"On the Rapidity of the Nervous Impulse in Tall and Short Individuals." By N. H. Alcock, M.D. Communicated by A. D. Waller, M.D., F.R.S. Received October 20,—Read November 19, 1903.

(From the Physiological Laboratory, University of London.)

Introduction.

While the effect of varying conditions on the rapidity of transmission of the nervous impulse has been fully studied, no research has yet been made as to whether the stature of the individual and the corresponding difference in the lengths of homologous nerves has or has not any influence on this rapidity, and as recent work has rendered it desirable that the question should be considered, the research here recorded was undertaken to this end.

Two series of observations were made: (1) On the frog; (2) on man.

Series I.—On Frogs' Nerves.

The following plan was adopted after several preliminary trials:—Two frogs differing in size were taken, and measurements made of the length from nose to anus, and of the sciatic from the emergence of the last nerve root to the gastrocnemius muscle. Gastrocnemius-sciatic preparations were then made, and placed side by side so that the nerves rested on a little hollow metal platform which was covered with thin sheet indiarubber, while the muscles were fixed just outside this. Crossing this platform were two pairs of electrodes, 20 mm. apart, and the two nerves lay across these, so that each nerve could be simultaneously excited at either pair of electrodes. The platform was covered by a hollow lid, and iced water was passed through both lid and platform, so that the nerves were equally cooled to about 0° C., while the muscles remained at room temperature (17—19° C.). The muscle twitch was recorded on a rapidly moving drum in the usual way. This method presents the advantage that while the nervous impulse is equally reduced in both nerves to an easily measureable speed, the delay due to the end-plates and muscles remains at its normal figure, any alteration in this latter factor bears, therefore, a lesser ratio to the total "latent period" than in experiments where both nerve and muscle are at ordinary temperature. The excitation was maximal throughout.

FIG. 1.

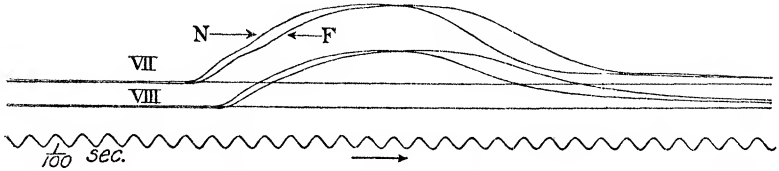

FIG. 1.—Frogs VII and VIII. Simultaneous record of twitches. N = excitation from "near" pair of electrodes. F, from "far."

Experiments.

	Length of frog.	Length of sciatic.	Observed time.	T° C.	Rate of impulse.
	mm.	mm.	secs.		m. per sec.
Frog I.....	67	45	0·0042	+1°·5	4·8
„ II.....	50·5	36	0·0038	..	5·3
„ III.....	74	49	0·0024	−0·2	8·3
„ IV.....	45	30	0·0026	..	7·7
„ V.....	71	50	0·0038	+0·3	5·3
„ VI.....	55	35	0·0036	..	5·6
„ VII.....	75	48	0·0028	+0·8	7·1
„ VIII.....	53	33	0·0030	..	6·7
			±0·001	..	±0·2
Mean of 4 long..	..	48	0·00330	..	6·07
„ 4 short..	..	33·5	0·00325	..	6·12

From these measurements it is clear that the rapidity of the nervous impulse *per unit length* is the same in all the frogs examined. As the total length of the sciatic varied from 50—30 mm., the time taken to travel from the central to the peripheral end was, therefore, proportionately longer in the larger frogs.

Series II.—On Man.

The method adopted was that elaborated by Waller.* A sensitive "Sandström" air tambour was connected by flexible tubing to a hollow rubber cylinder held in the hand, so that the contraction of the flexor muscles of the fingers would compress the cylinder. The excitation was by break induction shock to the median nerve, the anode† being applied (1) above the clavicle; (2) at the bend of the elbow internal to the biceps tendon, the kathode being applied on any

* Waller, A. D., 'Exercises in Practical Physiology,' Part III, p. 63.

† This position of the electrodes was found to give more concordant results than the usual practice of placing the kathode over the nerve.

convenient spot. The movement of the lever of the tambour was recorded on a pendulum myograph, this serving to open the break key in the primary circuit in the usual way. The strength of excitation was 6000 units of the standard Berne coil, worked by a 4-volt accumulator.

This method presents the advantages of a muscle-nerve preparation in a perfectly normal condition, and with a length of available nerve from 290—380 mm., but requires the most careful attention to details. It is necessary by preliminary experiments to ascertain (1) that the rate of the pendulum is invariable within the limits of error required; (2) that the break shock occurs always at the same place on the plate; (3) that the height of each contraction as recorded by the tambour shall be approximately the same; and (4) to use the same tambour and length of tubing throughout the series of experiments.

FIG. 2.

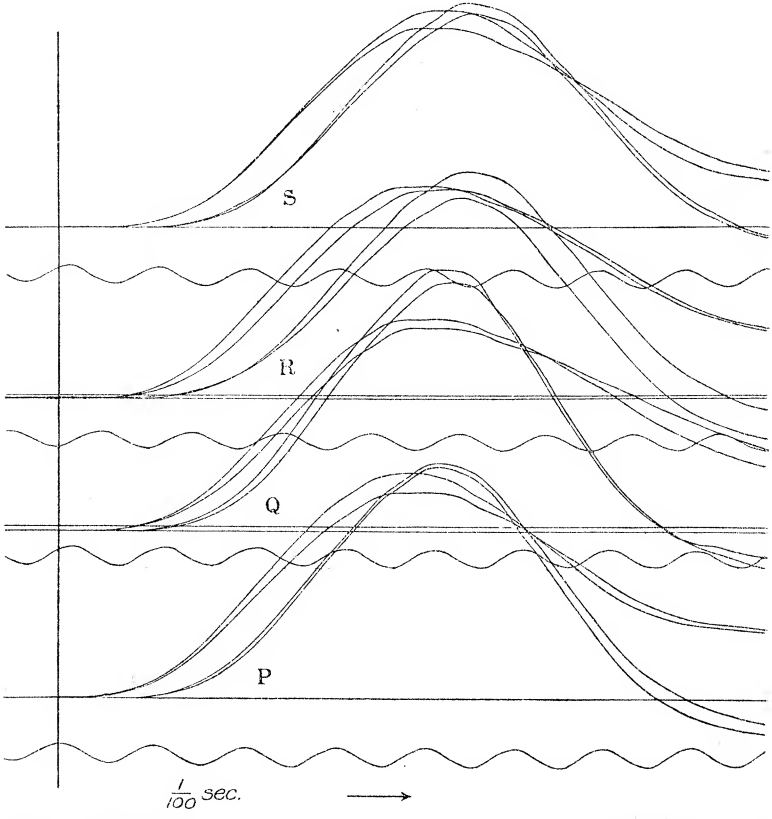

FIG. 2.—Subject C.D. Four consecutive experiments. Each consists of a pair of "near" and a pair of "far" excitations.

In order to keep a check on the experiments, these were made in two pairs (except in subject AB), two contractions of "near" excitation and two of "far" being superposed, any accidental error of any one contraction could be thus detected by the non-congruence of the curves.

It was found possible to obtain with care four or five consecutive experiments on the same subject without error in any one case greater than ±0·0001 second from the recording apparatus (fig. 2).

The reading of the time difference between the "near" and "far" curves presents some difficulty owing to the gradual rise of the lever at the commencement of the curve. In order to check my own readings, I asked Dr. T. G. Brodie to re-measure several of my curves, and his independent readings have agreed with mine within the limit of error of ±0·0001 second.

Experiments.

	Subject.	Height.	Length of nerve.	No. of experiments.	Mean value observed.	Rapidity of nervous impulse in metres per sec.
		mm.	mm.		sec.	
Short.	AB, age 21	1758	290	7 (single)	0·0044	66·5
Short.	CD, age 20	1684	295	15 (double)	0·0046	65·3
Tall.	EF, age 32	1814	380	6 (double)	0·0056	67·7
Tall.	GH, age 22	1930	360	12 (double)	0·0054	67·3

The results on the human subject agree with those obtained from the frog, namely, that *per unit length*, the rate of the nervous impulse is the same in all individuals examined, and the consequence follows that the time taken to traverse the limb nerves in a tall man is appreciably longer than in a short man. In the subjects examined, this difference was 0·001 second approximately, and if the reaction time to touch from the hand or foot were measured, this would—*cæteris paribus*—be from 0·003—0·004 second longer in the taller individuals, a distinct penalty to pay for their greater stature.

It will be observed that the mean velocity, deduced from the total number of forty experiments, is 66·8 metres per second (±0·1), a figure that is rather higher than that originally given by Helmholtz* and more recently by Waller.†

* Helmholtz u. Baxt. 'Monatsb. d. Berl Ak 1867 s. 228 (1870, s. 184).

† Waller, *loc. cit.*

Observations.

The results here recorded have an additional theoretical interest when considered in connection with the recently published work of Boycott.* This observer showed that in the sciatic of the frog the number of nodes of Ranvier is very approximately constant, and is independent of the length of the frog (33·2 in twenty-six frogs), and that the length of the internodes differs considerably, ranging from a length of 1803μ in large frogs to 249μ in small. *Per unit length* therefore there are many more nodes of Ranvier in the sciatic of a small than in that of a large frog, and as the present measurements show that the rapidity of the nerve impulse is the same in both classes of frogs, it follows that *the nodes of Ranvier are without any influence on this rapidity*, and that the internode cannot be regarded in the light of a functional unit in this connection.

As the length of the internode is proportional, both to the length of the whole nerve and to its diameter, it is not unreasonable to infer that this visible pattern furnishes a scale by which the invisible ultra-microscopic structure of the nerve-fibre can be estimated. It has been shown above that the scale of the visible pattern is without effect on the rate of the nervous impulse, it follows that the size of the invisible structure is also without effect, and this will modify such theories of nerve propagation as take this latter into account.

It gives me much pleasure to acknowledge the kind advice and assistance I have received from Dr. Waller in the prosecution of this research, and also to return my thanks to the gentlemen who lent themselves to the purpose of my experiments.

Conclusions.

(1) The rapidity of the nervous impulse *per unit length* is the same whatever be the stature of the individual.

(2) The time taken by this impulse to travel from the centre to the periphery is greater in taller individuals.

(3) The nodes of Ranvier exercise no influence on the rate of impulse.

* Boycott, 'Journal of Physiology' (in the Press).